BIBLIOGRAPHY OF INVESTMENT AND OPERATING COSTS FOR CHEMICAL AND PETROLEUM PLANTS

COMPILED BY W. I. BARNET

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A Century of Conservation

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UNITED STATES DEPARTMENT OF THE INTERIOR
J. A. Krug, Secretary
BUREAU OF MINES
James Boyd, Director

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by

W. I. Barnet[1/]

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INTRODUCTION

Under authorization of the Synthetic Liquid Fuels Act, Public Law 290, 78th Congress, the Bureau of Mines is doing research and development work on the production of liquid fuels from oil shale. When the development of a process reaches the point where adequate technical data are available, an economic evaluation is made on the basis of the estimated investment and operating costs of the process. The following bibliography was prepared as an aid in making these cost estimates, the purpose being not so much the tabulation of the actual cost figures as the listing of sources of information.

To give this compilation greater value, the scope was broadened to include equipment and operating costs for all processes in general use in the petroleum refining and chemical industries for which information was available. Besides searching the Chemical Abstracts and the Industrial Arts Index for pertinent references, the following journals were searched, beginning with about the 1930 issues and continuing through the September 1948 issues:

1. Chemical Engineering (formerly Chemical and Metallurgical Engineering)
2. Chemical Engineering Progress (formerly Transactions of the American Institute of Chemical Engineers)
3. Industrial and Engineering Chemistry

1/ Chemical engineer, Oil Shale Research and Demonstration Plant Branch, Bureau of Mines, Laramie, Wyo.

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4. Oil and Gas Journal

5. Petroleum Engineer

6. Petroleum Processing (formerly National Petroleum News, Technical Section)

7. Petroleum Refiner (formerly Refiner and Natural Gasoline Manufacturer)

Particular mention should be made of the many useful cost figures published during the last 2 years by Chemical Engineering. Beginning in the October 21, 1948, issue, the Oil and Gas Journal is publishing a series of articles by W. L. Nelson, in which are assembled costs pertinent to the petroleum industry.

ACKNOWLEDGMENTS

This bibliography was prepared as part of the oil-shale research and development program, which is under the direction of Dr. A. C. Fieldner, chief, Fuels and Explosives Division, Bureau of Mines, Washington, D. C., Dr. W. C. Schroeder, chief, Office of Synthetic Liquid Fuels, Washington, D. C., and R. A. Cattell, acting chief, Oil-Shale Research and Demonstration Plant Branch, Washington, D. C. This particular phase of the program is under the general supervision of H. P. Rue, supervising engineer, Petroleum and Oil-Shale Experiment Station, Laramie, Wyo., H. M. Thorne, engineer-in-charge, Oil-Shale Research and Development Laboratories, Laramie, Wyo., and under the direct supervision of W. I. R. Murphy, chief, Retorting and Refining Section, Laramie, Wyo.

Acknowledgment is made, with thanks, for the assistance rendered by the various members of the staff of the Bureau of Mines at Laramie, Wyo., Rifle, Colo., and Washington, D. C., who made valuable suggestions concerning the content and form of this compilation and who aided in preparing the manuscript for publication.

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ABSTRACTS

1. ALDEN, R. C. Conversion of Natural Gas to Liquid Fuels. Petrol. Eng., vol. 18, No. 4, Jan. 1947, pp. 148, 150, 152, 154, 156, 158.

Discusses German Fischer-Tropsch processes and American synthesis process as applied to natural gas. Gives investment cost for American

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processes, using natural gas, at $2,000 to $2,500 per barrel of liquid fuels produced, with liquid-fuel cost of approximately 5¢ per gallon (including 10 percent depreciation) using natural gas at 5¢ per M cubic foot. Products from 60 MM cubic feet natural gas are estimated to be:

4,100 bbl. motor fuel,
900 bbl. diesel fuel,
5,000 bbl. total refined hydrocarbon product,
360 bbl. oxygenated products, mostly ethyl alcohol.

2. ALDEN, R. C., and CLARK, A. Appraisal of Gas Synthesis Operations. Petrol. Processing, vol. 3, 1948, pp. 425-30.

A detailed study of the economic factors of the gas-synthesis process. Estimates for costs per BPD of production from gas and coal, respectively, are: Investment, $3,000 to $4,000 and $8,000; tons of steel, 6.1 and 8.7 to 12.0; manufacturing cost, 7.7 to 9.7 cents per gallon and 11.4 to 16.4 cents per gallon. A sample calculation of costs, in cents per gallon, is: Natural gas (at 10 cents per M cubic feet), 2.38 cents; operating costs, labor, supervision, technical administration, sales, 2.90 cents; maintenance, supplies, utilities, 2.00 cents; amortization (20 years), 1.31 cents; and interest (4%), 0.55 cents; total, 9.14 cents. A table gives the estimated yearly production of organic chemicals from a 7,000-BPD gas-synthesis plant.

19 references.

3. ALLEN, G. L., et. al. Utilization of Three Kids Manganese Ore in the Production of Electrolytic Manganese. I. Mining and Electrolytic Reduction. U. S. Bu. of Mines Rept. of Investigations 3815, June 1945, pp. 1-67.

Includes in discussion of production and use of manganese detailed cost estimates for a 40-TPD and a 10-TPD electrolytic manganese plant. Material balances, flow sheet, and proposed plant lay-out are shown. Equipment costs and operating costs (labor, power, and supplies) are given in detail for each size of plant.

4. ANDERSON, N. K., and STERBA, M. J. Small-scale Fluid-type Catalytic Unit Designed. Petrol. Refiner, vol. 24, No. 12, Dec. 1945, pp. 109-13; National Petrol. News, vol. 37, 1945, R-939-42; Petrol. Eng. vol. 17, No. 3, Dec. 1945, pp. 62, 64, 66, 69.

Describes UOP type MS fluid catalytic cracking unit, giving summaries of operating costs and production summary for charge rates of 900, 2,700 and 4,500 BPD with 3 catalysts. A summary is also given of operating costs for UOP liquid-feed catalytic polymerization units with capacities of 54 to 362 BPD.

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5. BECKET, F. M. Failure to Make Full Cost Analyses Wastes Technical Efforts Chem. Met. Eng., vol. 33, 1926, pp. 283-6.

Discusses, with examples, the waste of effort and money often resulting from misguided research owing to lack of a cost analysis. Outlines, briefly, method of making a cost estimate for a process.

6. BEHRENS, J. R. Estimating Installations of Chemical Equipment. Chem. Eng., vol. 54, No. 7, July 1947, pp. 106-7.

A general discussion of estimating technique.

7. BENT, R. D., and McCULLOUGH, J. H. Atlantic Refining Co.'s First Year with Unisol Process. Oil Gas Jour., vol. 47, No. 19, Sept. 9, 1948, pp. 95, 97, 100, 103.

A description of initial operation of the Atlantic Refining Co.'s 19,000-BSD Unisol Plant at Philadelphia. The actual utility requirements are given in following table:

	Per 1,000 bbl. gasoline
Steam, 150 lb. live	9,000 lb.
12 lb. exhaust	26,000 lb.
Total power	108 kw. hr.
Cooling and makeup water	29,000 gal.
Caustic prewash	20 lb.
Caustic process	74 lb.
Methanol	11 gal.

These quantities may be reduced in later operations.

8. BERGER, C. W. Naphtha, Lead Recovery by Centrifuge Process Proves Economical. National Petrol. News, vol. 29, No. 11, Mar. 17, 1937, pp. 152, 154-6.

Describes system for centrifugal separation of naphtha-doctor emulsion and regeneration of the doctor solution with air to lead oxide-caustic solution. Shows comparative sweetening costs, in chemicals used, and gasoline saving for the above (Bayway) process and the conventional process.

9. BLAND, W. F. Design Details, Operating Results of First Commercial Hypersorber. Petrol. Processing, vol. 3, 1948, pp. 635-8.

Describes Dow Chemical Co.'s Midland, Mich., Hypersorption plant. Utility requirements are given for this unit, including cooling water, fuel gas, steam, and electricity.

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10. BLISS, H. Data for Equipment Cost Estimates. Chem. Eng., vol. 54, No. 5, May 1947, pp. 126-38.

Presents cost data for pipe and tubing (various metals and nonmetallic), fittings, valves, heat exchangers, filters (presses, Sweetland, Oliver continuous vacuum), vessels and columns, manholes, nozzles, thickeners and classifiers, evaporators and crystallizers, absorption towers and packings, tanks and storage vessels, liquid pumps (centrifugal and rotary), agitated reaction vessels, and electric motors.

Continued with Chem. Eng., vol. 54, No. 6, June 1947, pp. 100-2.

11. BLISS, H. Equipment Cost Estimating Data, II. Chem. Eng., vol. 54, No. 6, June 1947, pp. 100-2.

Presents cost data for gas pumps (centrifugal, rotary, reciprocating compressors), crushing and grinding equipment (jaw crushers, crushing rolls, swing-hammer mills, and ball mills), and driers (drum, vacuum shelf, vacuum rotary and atmospheric rotary).

12. BLISS, H. The Cost of Process Equipment and Accessories. Trans. Am. Inst. Chem. Eng., vol. 37, 1941, pp. 763-804. Chem. Met. Eng., vol. 48, No. 12, Dec. 1941, pp. 88-98.

Presents cost data for pipe and tubing (various metals), pipe fittings, gate valves, heat exchangers, liquid pumps (centrifugal and rotary), gas pumps (centrifugal and rotary), thickeners, filters (press, Sweetland, Oliver continuous vacuum), crystallizers, driers (pan, drum, shelf, rotary, miscellaneous), absorption towers and packings, tanks and storage vessels, and linings (lead, asbestos felt + asphalt, and bituminous paint).

10 references.

(Note: These data are brought up to 1947 by Bliss: Chem. Eng., vol. 54, No. 5, May 1947, pp. 126-38; Chem. Eng., vol. 54, No. 6, June 1947, pp. 100-2.)

13. BROWN, C. O. Complete Ammonia Plants. Chem. Eng., vol. 54, No. 5, May 1947, p. 124.

Graphic breakdown of complete ammonia-plant costs for years 1925, 1935, and 1945.

14. BROWN, L. C., and TEARS, C. F. Quality of Lubricating Oils Improved by New Furfural Plant in Kansas Refinery. Oil Gas Jour., vol. 46, No. 10, July 12, 1947, pp. 58-9, 96-8, 101.

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Describes furfural solvent extraction plant, built in late 1946 at a cost of $750,000. Design capacity is the processing of 2,200 BPD of dewaxed neutral stock (200 SSU at 100° F.) or 1,050 BPD of dewaxed acid-treated bright stock (165 SSU at 210° F.). Average daily solvent loss is 42 gallons, representing 0.06 percent daily loss based on hourly circulation rate of solvent.

15. BRUMMERSTEDT, E. F. Design and Construction of a 33-foot Diameter, Arc-welded, Vacuum Fractionating Tower. National Petrol. News, vol. 35, 1943, pp. R-74-6, 78-80, 82-3.

Describes new method of design and construction of 37,000-BPD fractionating tower. Unit costs are given for materials and construction, and a cost comparison is made between a welded tower and a riveted tower.

16. BRUMMERSTEDT, E. F. Discussing Economic Design of Modern Pressure Vessels, 1. Factors Affecting Cost of Tanks. National Petrol. News, vol. 36, 1944, pp. R-282-3.

Presents analytical methods for determining economic design of pressure tanks (under API-ASME Code for Unfired Pressure Vessels). Formula given for calculating cost of tank from its dimensions, steel cost in cents per pound, and shop labor rates.

Continued with National Petrol. News, vol. 36, 1944, pp. R-362-4.

17. BRUMMERSTEDT, E. F. Economic Design of Pressure Vessels, 2. Shape of Heads. National Petrol. News, vol. 36, 1944, pp. R-362-4.

Gives formulas for calculating cost of heads for pressure vessels.

Continued with National Petrol. News, vol. 36, 1944, p. R-447.

18. BRUMMERSTEDT, E. F. Economic Design of Pressure Vessels, 3. Materials and Construction Factors, National Petrol. News, vol. 36, 1944, p. R-447.

Discusses effect grades of steel and construction factors have on cost of pressure vessels. Unit material costs are given.

Continued with National Petrol. News. vol. 36, 1944, pp. R-603-4.

19. BRUMMERSTEDT, E. F. Economic Design of Pressure Vessels, 4. Analysis of External Pressure Vessels. National Petrol. News, vol. 36, 1944, pp. R-603-4.

Gives formulas for calculation of optimum wall thickness and number of stiffening rings required for external pressure vessel for most economical construction cost.

Continued with National Petrol. News, vol. 36, 1944, p. R-684.

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20. BRUMMERSTEDT, E. F. Economic Design of Pressure Vessels, 5. Gas Storage, Miscellaneous Factors. National Petrol. News, vol. 36, 1944, p. R-684.

Discusses relative cost of storing gas at various pressures. Gives price per cubic foot for atmospheric holders ranging in capacity from 250 cubic feet to 250 M cubic feet. Discusses effect of foundation cost on selection of pressure vessel size and shape.

Unit costs of gas holders (atmospheric) excluding foundations:

Capacity (cu. ft.)	Price/cu. ft.
25,000	$0.56
50,000	0.44
250,000	0.33

21. BRYANT, G. A. Plant Design for Minimum Cost. Chem. Eng., vol. 54, No. 5, May 1947, pp. 113-6.

Detailed discussion of factors affecting cost of buildings: plant location, basic plant planning, building services, and facilities. Gives comparative construction costs for various types of buildings. Gives Austin index of industrial building costs for 1913 to 1947.

22. BUELL, W. H. Calculating Payout Time for Equipment Investments. Chem. Eng., vol. 54, No. 10, Oct. 1947, p. 97.

Formulas are given relating capital investment, interest, taxes, profit, etc.

23. BULLOCK, H. L. Vibrating-Screen Estimation. Chem. Eng., vol. 54, No. 6, June 1947, pp. 97-9.

Presents a simple method for the approximate determination of vibrating-screen costs.

24. CALDWELL, H. B., and KOHLINS, W. D. Some Aspects of the Economics of Evaporation. Trans. Am. Inst. Chem. Eng., vol. 42, 1946, pp. 495-509.

Tables show installed cost and complete operating costs for 4, 5, 6, and 7-effect evaporators for 100-TPD and 300-TPD pulp mills having steam costs of 10¢, 20¢, and 30¢ per M pound for black liquor evaporation in sulfate pulp mills. Evaporation costs are also given on viscose rayon plants and for electrolytic caustic soda plants. A brief discussion gives the effect of solution characteristics on the feasible number of effects.

25. CAMP, H. W., and MANN, L. D. Depreciation of Refinery Equipment. Oil Gas Jour., vol. 28, No. 43, Mar. 13, 1930, pp. 54, 168-9.

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Lists and discusses depreciation rates on refinery equipment based on experience in Mid-Continent field.

26. CAMPBELL, O. F., and KIMBALL, T. B. Regenerative-type Air Heater for Refinery Is Described. National Petrol. News, vol. 33, 1941, pp. R-168, 170, 172.

Describes the Ljungstrom air heater and its application to a de Florez down-draft cracking still furnace. Compares fuel and power costs for a 70 MM B.t.u./hr. still with and without the air heater.

27. CAREY, J. S. Polymerization Costs, Yields. National Petrol. News, vol. 28, No. 45, Nov. 4, 1936, pp. 64-6, 68-71.

Describes unitary thermal polymerization process, giving yields from typical feed stocks and operating costs.

28. CAREY, J. S., and ORTENDAHL, H. W. Catalytic Cracking Economics Complicate Comparisons. National Petrol. News, vol. 32, 1940, pp. R-370-2, 375.

Discussion of catalytic cracking factors: (1) catalyst activity, (2) space rate, (3) operating conditions, and (4) regeneration conditions. Graph shows relationship of plant investment cost to catalyst space rate. Operating costs for a Houdry catalytic cracking plant are analyzed, including operating labor, utilities, catalyst cost, maintenance, and royalty.

29. CARVLIN, G. M. Thirty-five Tons H_2SO_4 Per Day from Refinery Gases. National Petrol. News, vol. 30, 1938, pp. R-268, 270, 272, 274.

Describes plant for H_2S removal from liquids and gases with sodium phenolate solutions and production of H_2SO_4 from the H_2S. Material balance and itemized operating costs are given for plant. The operating cost is \$3.25 per ton of 66° Baumé sulfuric acid.

30. CHEM. ENG. Building Costs. Vol. 54, No. 5, May 1947, p. 111.

A brief discussion of cost of building construction with some labor and dollar per square foot data to show great variability in cost of buildings.

31. CHEM. ENG. Process Equipment Cost Estimation. Vol. 54, No. 5, May 1947, pp. 107-8.

Introduction to "Chem. and Met." report on above topic.

32. COE, E. H. These Short-cuts Will Speed Your Design and Estimation of Tanks. Chem. Eng., vol. 55, No. 9, Sept. 1948, pp. 107-9.

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Graphs are given for rapid design of unfired vessels up to 1,000 gallons capacity and 150-p.s.i. operating pressure. Graphs are also shown giving cost of flat-head metal tanks, with and without jacket, of plain steel, rubber-lined, stainless, and Ni-clad for capacities up to 1,400 gallons, and of flat-head glass-lined tanks and reactors, with and without jacket, for capacities up to 2,800 gallons.

33. CONSIDINE, D. M. Estimation of Instrument Costs. Chem. Eng., vol. 54, No. 7, July 1947, pp. 108-9, 122.

Gives equipment, accessory, and installation costs for different types of instruments, with discussion. Gives table of installed cost of instruments as percent of total equipment cost, with discussion.

34. CONWAY, M. J. Equipment for Low-cost Oxygen Production. Petrol. Refiner, vol. 26, No. 6, June 1947, pp. 129-33.

Discusses production of O_2 by liquefaction and fractionation of air. Gives cost of O_2 in relation to plant capacity and breakdown of total cost for different plant capacities.

35. DICKSON, R. A. Determining Costs of Tanks, Spheres, and Drums. Chem. Eng., vol. 54, No. 8, Aug. 1947, p. 122.

Gives formula for calculating cost of tanks, spheres, and drums:

$$C = A \times B^{0.3} \times X^{0.7},$$

where C is cost of the container, A is unit cost, B is capacity of this standard size, and X is cost of the container whose cost is desired. Graph gives 1946 unit cost vs. capacity for tanks, spheres, and drums. This formula can also be given as:

$$Y_2 = Y_1 (X_2/X_1)^{0.7},$$

See Editor's note, Chem. Eng., vol. 54, No. 12, Dec. 1947, p. 125.

36. DICKSON, R. A. How "N" System Simplifies Piping Cost Estimation. Chem. Eng., vol. 54, No. 11, Nov. 1947, pp. 121-3.

The "N" system is based upon the predictable relationship that the cost of a string of pipe of any size bears to the cost of the same string in another size. Hence, only the cost of the "reference" string in each kind of pipe need be kept up to date.

37. DOWNS, C. R. Impact of Tonnage Oxygen on American Chemical Industry. Chem. Eng., vol. 55, No. 8, Aug. 1948, pp. 113-7, 121.

A discussion of the production of O_2 in large quantities and its possible use in various industries. Estimated plant and operating costs are given for a 100-TPD and a 1,000-TPD plant in the following table:

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	Plant capacity	
	100-TPD	1,000-TPD
Estimated plant cost	$1,000,000	$4,000,000

Operating cost	Dollars/ton O2	
Steam (30¢/M lb.)	1.56	1.46
Electricity (0.5¢/kw. hr.)	0.11	0.11
Water (1¢/M gal.)	0.35	0.30
Labor ($67/operating day)	0.67	0.07
Maintenance (2.5% of plant cost)	0.72	0.29
Fixed charges (12.5% of plant cost)	3.61	1.44
Total operating cost	7.02	3.67

38. ECKHARDT, H. Centrifugal Separator Costs. Chem. Eng., vol. 54, No. 5, May 1947, pp. 121-3.

Tabulations of costs for centrifugals: basket-type, horizontal-shaft, conveyor-discharge, and high-speed.

39. ECKHARDT, H. Needed: Standard Cost Estimating Data for the Process Industries. Chem. Eng., vol. 53, No. 9, Sept. 1946, pp. 104-5.

Points out the need for and suggests the method of assembling and correlating equipment and operating cost data.

40. ECKHARDT, H. Price and Cost - An Analysis. Chem. Eng., vol. 54, No. 5, May 1947, p. 108.

Differentiates between price and cost. Cost depends on capacity of equipment as well as price. Suggests compilation of cost data on capacity basis for various types of equipment.

41. EDITORIAL STAFF. Depreciation Rates for Process Equipment. Chem. Met. Eng., vol. 45, No. 2, Feb. 1938, pp. 80, 99.

Gives table of probable useful life and depreciation rates for chemical process equipment from bulletin of the Bureau of Internal Revenue.

42. EDITORIAL STAFF. Equipment Freight Cost. Chem. Eng., vol. 54, No. 5, May 1947, p. 125.

Formulas are given for estimating freight rates for CL and LCL for Eastern United States and transcontinental shipments.

43. EDITORIAL STAFF. Estimating Spray Dryers. Chem. Eng., vol. 54, No. 5, May 1947, p. 125.

Brief discussion and chart are given for estimating price and horsepower of Gray-Jensen spray driers (Swenson Evaporator Co.).

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44. EDITORIAL STAFF. Indexes in the Plant Cost Picture. Chem. Eng., vol. 54, No. 5, May 1947, pp. 109-11.

Discusses need of equipment cost index. Gives data from Bureau of Labor Statistics on cost indexes for 16 classes of general machinery and equipment for 1939 to Jan. 1947. Presents new plant cost index calculated from 1/3 Engineering News Record construction index and 2/3 Bureau of Labor Statistics composite equipment index.

45. EDITORIAL STAFF. Metals and Alloys. Chem. Met. Eng., vol. 47, 1940, pp. 603-4.

Table is given of prices of various stainless steels in the following shapes: bars, drawn wire, structural, plate, sheet, hot and cold-rolled strip, and forging billets.

46. EDITORIAL STAFF. Refrigeration Costs. Chem. Eng., vol. 54, No. 5, May 1947, pp. 125, 138.

Brief discussion and graph for estimating complete refrigeration plant cost based on evaporator temperature.

47. EDITORIAL STAFF. Synthetic Fuels. Chem. Eng., vol. 55, No. 6, June 1948, pp. 131-8.

A detailed discussion of the possible future of synthetic fuels and of present research and development work. E. V. Murphree's cost estimates, submitted Feb. 25, 1948, to Oil Subcommittee of House Armed Service Committee, are quoted below:

		Crude oil	Natural gas	Coal*	Oil shale**
Investment ($/BPD)	Max. dist.	4,300	7,400	7,600	6,100
	Max. gaso.	6,500	8,200	8,500	8,400
Steel (tons/BPD)	Max. dist.	5.7	7.1	4.6	5.7
	Max. gaso.	7.8	7.9	5.2	7.4
Percent gasoline in liquid products	Max. gaso.	87	90	89	87
Raw material, price		$2.78/ bbl.	10¢/M cu. ft.	$3.20/ ton	$1.00/ ton
Total gasoline cost (¢/gal.)	Max. gaso.	14.1	12.8	16.6	16.0

* By gasification, in the East.

** Raw shale oil transported by pipe line to Calif. for refining.

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48. EMERT, F. L. Lion Oil Co. Starts Operation of TCC Unit. Petrol. Refiner, vol. 26, No. 12, Dec. 1947, pp. 85-9.

Describes new TCC unit designed to process 4,500 BPD of fresh gas oil with 900 BPD of recycle stock, costing approximately $1,500,000.

49. EVANS, L. P. Comparison of Bead and Clay Catalysts. Oil Gas Jour., vol. 44, No. 47, Mar. 30, 1946, pp. 167-8, 172-3, 177-8, 181, 183.

Gives economic comparison for use of bead and clay catalysts in a TCC plant. Gives clay catalyst cost as $80 per ton (f.o.b. catalyst manufacturing plant), which, at 20 percent H_2O, is equivalent to $100 per ton on the dry basis. Bead catalyst cost (dehydrated form) is $240 per ton. Average catalyst make-up for 10,000-BPD unit is 1 to 1.5 tons per day for beads, as compared to 3 to 4 tons per day for clay.

50. FENSKE, M. R. Hydrogenation. Unit Processes in Organic Synthesis, 1938, pp. 427-9. P. H. Groggins, editor, McGraw-Hill Book Co., New York.

Total cost and cost breakdown is given for production of H_2 from water gas, by electrolysis, and from hydrocarbon gases in large hydrogenation plants. Compression costs are also given. Actual cost of H_2 only for hydrogenation of petroleum, tar, and coal is estimated at a fraction of a cent to 2 cents per gallon of hydrogenated product.

51. FIELD, J. H. Electric Generating Plants - A Discussion of Installation Costs. Oil Gas Jour., vol. 45, No. 7, June 22, 1946, pp. 106, 109, 112, 114, 117, 118, 121.

Presents installed cost data for 30 generating plants ranging from 35 to 2,500 kw. Practically a straight-line relationship exists between plant capacity in kilowatts and plant investment in dollars. The investment cost amounts to about $120 per kilowatt for large as well as small plants. Chart and tables show breakdown of operating costs for plants of different size.

52. FOSTER, A. L. Cities Service, Kellogg Announce Merger of Synthetic Programs. Oil Gas Jour., vol. 46, No. 44, Mar. 4, 1948, p. 42.

Makes public Cities Service's and Kellogg's 2 year-old association. L. H. Harvison, Kellogg executive vice president, estimates cost of Fischer-Tropsch plant using natural gas as about $4,000 per BPD of hydrocarbon products.

53. FOSTER, A. L. Cost Factors in Postwar Alkylation. Oil Gas Jour., vol. 44, No. 25, Oct. 27, 1945, pp. 96-7, 119, 120, 123, 124.

Tabulates and discusses labor and commodity requirements for HF alkylation plants.

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54. FOSTER, A. L. Thermal Cracker Expanded into TCC Unit. Oil Gas Jour., vol. 46, No. 15, Aug. 16, 1947, pp. 78-82.

Total cost of 3,000-BPD TCC unit converted from a conventional 2-coil thermal cracking unit is given as $250 per BPD of throughput capacity.

55. FOWLER, F. C., and BROWN, G. G. Cost of Pressure Vessels and Pressure Fractionating Columns. Trans. Am. Inst. Chem. Eng., vol. 39, 1943, pp. 241-54.

Gives January 1941 net costs for parts of pressure vessels and fractionating columns, including shell, liners, nozzles, manholes, couplings, tray supports, bubble trays, platforms, handrails, ladders, insulation, also stress relieving, x-ray inspection and freight.

56. FOX, L. E. Estimation of Field-erected Tanks. Chem. Eng., vol. 54, No. 8, Aug. 1947, pp. 100-1, 122.

Gives a basic and a quick method for estimating cost of field-erected storage tanks, allowing for material, location, type of construction, and other factors. Graphs give unit costs for field-erected steel tanks; weights of standard, API, flat-bottom, cone-roof tanks; and cost for standard steel tanks and for alloy and clad-steel tanks.

57. FRAME, A. P. A Refiner's Look at Gasoline Quality. Petrol. Refiner, vol. 26, No. 10, Oct. 1947, pp. 106-11.

Primarily an article attempting to forecast the composition and octane rating of gasoline produced in 1950, demonstrating thus the continued expansion in use of catalytic cracking. States that capital investment for a catalytic cracking unit producing 7,000 BPD of gasoline is about $800 per BPD of gasoline capacity; for a 1,500-BPD plant the cost is about $1,200 per BPD of gasoline capacity.

58. FRANKLIN, W. B. Comparative Economics of Refrigerated and Pressure Light Oil Storage. National Petrol. News, vol. 29, No. 26, June 30, 1937, pp. 120-4.

Presents an economic comparison of various types of storage vessels for butanes. Graph shows relationship between investment cost and size of storage tanks for various pressures. Tables are given of investment and operating costs, and comparison is made between pressure and refrigerated storage costs.

59. FUNDER, M. Choosing Pipeline Sizes for Maximum Economy. Chem. Met. Eng., vol. 39, 1932, pp. 602-3.

Gives graph of most economical flow velocity and corresponding friction loss for 2- to 30-inch pipe. Shows, graphically, the total yearly costs of various pipe sizes, at various flow rates, and the economical range for each size.

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60. FUWA, T. An Economic Study of Evaporators. Chem. Met. Eng., vol. 31, 1924, pp. 185-8.

Discusses evaporator investment costs and gives graph relating cost to area of heating surface for five types of evaporators. Discusses operating costs and gives examples of methods used in their calculation.

61. FUWA, T. Crushing and Grinding Costs. Chem. Met. Eng., vol. 31, 1924, pp. 268-71.

Includes a graphic presentation of crushing and grinding equipment costs and a discussion of operating costs based on typical cases selected from industrial practice in the grinding of phosphate rock and limestone.

62. FUWA, T. How Shall We Calculate the Cost of Exhaust Steam? Chem. Met. Eng., vol. 31, 1924, p. 150, discussion p. 355.

Compares calculation of exhaust-steam cost on following bases: (1) available power, (2) available heat, (3) combination of (1) and (2), and (4) purchase price from an external source.

63. GARDNER, E. D., and BELL, C. N. Proposed Methods and Estimated Costs of Mining Oil Shale at Rulison, Colorado. U. S. Bu. Mines Inf. Circ. 7218, Nov. 1942, 59 pp.; Oil Gas Jour., vol. 41, No. 36, Jan 14, 1943, pp. 47, 49.

A discussion of the characteristics of the oil-shale deposits near Rulison, Colo., and of the proposed methods of mining same. Estimated costs are given for mining 20-foot, 44-foot, and 106-foot beds.

64. GARY, W. W., and ADAMS, N. R. Economics of Reforming and Leading Mid-Continent Gasoline. National Petrol. News, vol. 29, 1937, pp. R-83-4, 86-7, 89 and 90.

Presents equation and charts relating cracking, reforming, and leading for most economical production of motor fuel of given octane rating.

65. GISLER, H. J. Lehigh Navigation Coal Co. Deco Trefoil, vol. 12, No. 5, Sept.-Oct. 1948, pp. 5-12.

A detailed description of the operation of a froth flotation plant of the Lehigh Navigation Coal Co. at Tamaqua, Pa., for the recovery of fine coal from washery-water solids. The following operating costs are estimated on the basis of 525 TPD output, with a 2-shift day, 6 days a week.

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Operating costs

Flotation plant:	$ per ton output
Labor	$0.130
Power	0.040
Reagents	0.061
Maintenance, material and labor	0.072
Total plant operation	$0.303

Pumping and impounding:	
Labor	0.048
Power	0.066
Maintenance, material and labor	0.033
Total pumping and impounding	0.147
Total operating cost	0.450

66. HAPPEL, J., ARIES, R. S., and BORNS, W. J. Estimating Chemical Engineering Equipment Costs. Chem. Eng., vol. 53, No. 10, Oct. 1946, pp. 99-102.

Gives Engineering News Record (ENR) construction-cost index to July 1946 and ENR location factors for the summer of 1946; also equipment and installation costs for vessels, towers, heat exchangers, pumps and compressors, piping, and valves.

See Chem. Eng., vol. 53, No. 12, Oct. 1946, pp. 97-100.

67. HAPPEL, J., ARIES, R. S., and BORNS, W. J. Equipment Costs and Other Items in Engineering Economics. Chem. Eng., vol. 53, No. 12, Dec. 1946, pp. 97-100.

Gives equipment and installation costs for instruments, electric equipment (motors, transformers, lighting), steam generators and tube furnaces, tanks and gas holders, concrete, structural steel, insulation, fireproofing and painting, buildings, and other construction expenses (indirect construction expense, contingencies, and contractor's fee). Gives, also, cost of labor (unskilled, skilled, and foremen) and utility cost ranges for fuel, steam, water, electricity, and air. Includes table of service life for various groups of process equipment in various industries. Discusses items of plant investment other than equipment (royalty, catalyst and chemical costs, running inventory) and operating costs and expenses (raw materials, income, operating expenses - labor, works expense, maintenance, utilities, sales expense, and overhead - amortization, taxes and insurance). Discusses briefly methods of economic evaluation.

68. HARBERT, W. D. Economic Distillation Design, a Study of the Comparative Importance of the Distillation Variables. Petrol. Refiner, vol. 27, No. 4, April 1948, pp. 106-9.

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A mathematical method is presented for the definition of the economic optimums in the first design of a distillation plant. The variables considered are (1) separation obtained between components in overhead and bottoms, (2) heat effects of feed and reflux, and (3) number of "plates."

69. HARRIS, J. McA., JR. Process Design - Chemical Engineering Economics. Chem. Eng. Progress, vol. 44, 1948, pp. 333-5.

Lists the factors included in manufacturing cost and data needed for their evaluation. Quotes cost-distribution figures. Gives breakdown of a preliminary cost estimate for production of formaldehyde in a German plant in July 1944. Discusses process design data of economic nature that should be obtained in the laboratory, and gives a check list of information that should be available at the close of pilot-plant operations.

70. HARTS, H. W. Alkylation Feed Stock Produced in Natural Gasoline Plants. National Petrol. News, vol. 33, 1941, pp. R-153-4, 156, 158.

Discusses separation of iso-pentane and iso-butane from natural gasoline. On basis of new plant at Salem, Ill., estimated plant investment cost for separation of iso-butane from natural gasoline is $11.25 per gallon - day; and operating and maintenance costs (not including loading losses, tank-car rentals, and payment for gas) are $0.0082 per gallon.

71. HEINECKE, G. W. Estimating Refinery Construction Costs. Petrol. Eng., vol. 3, No. 11, July 1932, pp. 37-8.

A general discussion of items entering into estimation of refinery construction costs, with a summary construction-cost estimate sheet shown.

72. HERNLUND, R. W. Operating Results With the W.K.E. (HMS) Mobil-Mill. Mines Mag. (Colo.), vol. 38, No. 7, July 1948, pp. 17-20, 45.

Presents the physical and metallurgical operating characteristics of the W.K.E. (HMS) Mobil-Mill, a semiportable, heavy-media, separation plant. The following summary of estimated operating costs is given for a plant running on an 8-hour day with a feed rate of 20 TPH:

Cost Item	Cents per ton
1. Labor	11.2
2. Power	6.7
3. Media	1.7
4. Supplies and repair parts	4.0
5. Overhead and miscellaneous	10.0
Total costs	33.6

Investment cost of a Mobil-Mill is about $50 per ton of capacity.

73. HOLADAY, W. M. Cost of Making Higher Octanes. Petrol. Processing, vol. 3, 1948, pp. 107-9.

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Discusses higher refinery investment cost required to produce higher octane gasoline. Graph shows relationship of refinery investment to octane number of gasoline produced. A construction-cost index graph is also given for 1925-1948.

74. HOLSTEN, F. E., and VOTRIAN, C. E. Refinery Cost vs. Selling Price. Oil Gas Jour., vol. 28, No. 42, Mar. 6, 1930, pp. 192, 296, 298.

A general discussion of determining refinery operating costs.

75. HOOVER, C. O. The Hoover Process, Use of Oxygen in Gasoline Treating. Petrol. Refiner, vol. 27, No. 7, July 1948, pp. 99-103.

A description of the Airco-Hoover copper-sweetening process. A cost breakdown is given for 1 month's operation, in which 84,000 barrels of sour products were treated. The quantity and unit cost of the chemicals are given. The total operating cost is itemized as follows:

Item	Dollars per month	Cents per barrel
Insurance and taxes	41	0.049
Administration and supervision	225	0.268
Operating labor	577	0.687
Repair labor	218	0.260
Repair material	138	0.164
Operating supplies	20	0.024
Chemicals	604	0.719
Utilities	1,335	1.589
Product losses	86	0.102
Total cost	3,244	3.862

Unit costs of above items are also given.

76. HORNBERG, C. V., KEIPER, E. D., and CHESNEY, R. M. Use of Bead Catalyst in Commercial Houdry Units. Oil Gas Jour., vol. 46, No. 12, July 26, 1947, pp. 214-6, 242-3.

Discusses advantages of Socony-Vacuum synthetic bead catalyst over the Houdry pelleted synthetic catalyst. Gives cost of bead catalyst as 12 cents per pound and of Houdry pelleted catalyst as 20 cents per pound.

77. HOW, H. Short-cut Estimation of Welded Process Vessels. Chem. Eng., vol. 55, No. 1, Jan. 1948, pp. 122-6.

Gives charts permitting quick estimate of cost of gas cutting, plate rolling, edge preparation, welding labor, welding rod, and flux for butt and fillet welds in various steels and alloys; several kinds of nozzles; and the machining of plate flanges and heads.

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78. JACKSON, D. H. Ejectors and Condensers. Chem. Eng., vol. 54, No. 5, May 1947, pp. 123-4.

Prices are given for steam jet ejectors and barometric condensers.

79. KELSO, G, et al. Design and Operation of a Small-scale Thermofor Catalytic Cracking Unit. Petrol. Refiner, vol. 26, No. 8, Aug. 1947, pp. 98-103.

Describes design and operation of a TCC unit having a reactor charge capacity of 3,000 BPD. Estimated cost of similar plant is $250 to $300 per BPD of reactor-charge capacity.

80. KELSO, G. Small Refiner's Chance of Staying in Business. Petrol. Refiner, vol. 26, No. 10, Oct. 1947, pp. 112-3.

Gives graph relating investment cost to gasoline production capacity for installation of all new TCC equipment and for revamping existing equipment.

81. KIMBALL, T. B., and SCOTT, J. A. Refinery Tools for the Manufacture of High-octane Gasoline. Petrol. Processing, vol. 3, 1948, pp. 659-64, 666; Petrol. Refiner, vol. 27, No. 6, June 1948, pp. 116-23.

A review of various methods for production of high-octane gasoline. A comparison is made of average calendar day costs of various types of cracking units, including thermal, fluid, TCC, and Houdry, with detailed breakdown of costs. Charge capacity basis is approximately 10,000 BPD of feed stock.

82. KINCKINER, R. A. Investments and the Engineer. Chem. Eng. Progress, vol. 43, 1947, Trans. pp. 183-8.

Presents ENR construction cost index through 1945 with brief discussion of price indexes. Analyzes factors making up investment costs and illustrates necessity of considering working capital as part of investment.

83. KLEINSCHMIDT, R. V. Generation vs. Purchase of Process Power. Chem. Met. Eng., vol. 39, 1932, pp. 200-1.

Discusses relative economics of generated and purchased power. Tabulates several power costs on basis of coal and investment costs, etc.

84. KOMINEK, E. G. Evaluation of Demineralization Methods. Chem. Eng. Progress, vol. 44, 1948, pp. 697-702.

A brief review of the methods and cost of demineralizing water. The relation between demineralizing costs and solids concentration in the water is shown by a graph that compares the following processes: single-, double-, and triple-effect evaporators, ion exchange, and compression still using electricity or fuel oil.

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85. LANG, H. J. Engineering Approach to Preliminary Cost Estimates. Chem. Eng., vol. 54, No. 9, Sept. 1947, pp. 130-3.

A systematic method for preliminary cost estimating should start with site plan, process flow sheet, preliminary engineering flow sheet, preliminary plot and equipment arrangement plans, preliminary equipment and instrument lists, and preliminary material and energy balances. Shows a typical summary sheet and discusses items on sheet, which are listed below:

	Material	Labor	Total
A. Yard improvements	x	x	x
B. Buildings, including services	x	x	x
C. Process equipment	x	x	x
D. Process piping	x	x	x
E. Electrical installations	x	x	x
F. Service facilities	x	x	x
	x	x	x
G. Contingency (- - %)			x
H. Insurance and taxes (- - % of labor) ..			x
I. Premium time (- - % of labor)			x
			x
J. Field office expense including temporary construction			x
K. Home office expense including overhead.			x
Total cost not including fee			x

See Chem. Eng., vol. 54, No. 10, Oct. 1947, pp. 117-121.

86. LANG, H. J. Cost Relationships in Preliminary Cost Estimation. Chem. Eng., vol. 54, No. 10, Oct. 1947, pp. 117-21.

A study of cost estimates for 14 processing plants, some of which are compared with actual costs to show accuracy and types of errors. Percentage costs are given for various plant elements in plants of various sizes and types, presenting a simplified method for quick estimates of complete plants, requiring detailed estimation of the processing equipment only. See Chem. Eng., vol. 55, No. 6, June 1948, pp. 112-3.

87. LANG, H. J. Simplified Approach to Preliminary Cost Estimates. Chem. Eng., vol. 55, No. 6, June 1948, pp. 112-3.

On the basis of study reported in earlier articles (Chem. Eng., vol. 54, No. 9, Sept. 1947, pp. 130-3, and Chem. Eng., vol. 54, No. 10, Oct. 1947, pp. 117-21), factors are given for calculating total estimated plant cost from delivered equipment cost by multiplication of latter by the factor:

For solid processing plants - 3.10
For solid-fluid plants .... - 3.63
For fluid processing plants - 4.74

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The total plant cost obtained by this method should be within 10 to 15 percent of the cost obtained by a preliminary estimate. Four examples are given.

88. LEWIS , R. C. Cost Accounting in Refinery Construction. Petrol. Refiner, vol. 25, No. 1, Jan. 1946, pp. 118-23.

Discusses value to both contractor and refinery operator of a good construction cost accounting system. Gives detailed suggestions for the design and use of a cost-accounting code.

89. LOBO, W. E. Low Pressure Oxygen Process. Petrol. Eng., vol. 18, No. 8, May 1947, pp. 120, 123, 126, 128.

Discusses Kellogg's low-pressure oxygen process. Gives some data on plant and utility requirements and production costs for 95 percent pure O_2. Investment cost is estimated at $5,000 per TPD of O_2 and production cost at $3.50 per ton (15¢ per std. M cu. ft.) for a 400-TPD plant. Basis is maintenance at 3 percent, taxes and insurance at 1.5 percent, and depreciation at 10 percent of plant cost per year.

90. LOCKHART, F. J. Multi-column Distillation of Natural Gasoline. Petrol. Refiner, vol. 26, No. 8, Aug. 1947, pp. 104-8.

Presents economic comparisons of a number of possible process arrangements of distillation sections in natural-gasoline plants. Gives 20 cents per pound of total weight for 1946 cost of complete distillation columns, erected, in the Los Angeles area. Cost range in 1946 for heat exchangers, installed basis, was $4 to $8 per square foot of transfer area. Operating charges used in analysis were:

150 p.s.i. steam	20¢/M lb.
Cooling water	0.5¢/M gal.
Power	0.5¢/kw. hr.
Fuel	15¢/MM B.t.u.

91. MACK, F. B. Economics of Catalytic Polymerization of Butanes. National Petrol. News, vol. 31, 1939, pp. R-188, 190-2.

Describes operation of butane polymerization plant using UOP catalytic process. Costs include 0.5 cents per gallon for royalty and 0.5 to 0.75 cents per gallon for catalyst cost. Runs are about 40 days, with shutdown cost of $800 for a plant with 1,000 BPD butane charge capacity. Other costs are not given.

92. MAHR, H. W. Economic Life and Catalysis Costs of Contact Catalysts. Trans. Am. Inst. Chem. Eng., vol. 34, 1938, pp. 353-73.

Catalyst costs in processes using contact catalysts are segregated, and their nature is discussed. They are grouped into initial expenditures for catalysts, investment charges for precious metals, and losses incurred

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by inactivation of catalysts. Two types of catalysts are indicated on the basis of the above groups. The costs are used in typical operating problems for obtaining minimum catalyst cost. Methods of appraising catalysts and determining catalytic process conditions on the basis of minimum cost are illustrated.

93. MANDELBAUM, M. R., and SWANSON, P. Comparative Costs of Vapor Phase and Other Treating Processes. National Petrol. News, vol. 28, No. 50, Dec. 9, 1936, pp. 69-72.

Compares operating costs of the Gray vapor-phase clay treatment and acid treating and rerunning.

94. MARSTON, A., and AGG, T. R. Engineering Valuation, 1936. McGraw-Hill Book Co., New York.

This is a good reference for methods of valuating property. Pre-construction cost estimates are not discussed. Pages 497 to 514 give a compilation of average service life of industrial property units.

95. McCLUER, W. G., DICKINSON, J. T., and FORREST, H. O. Application of Propane to Manufacture of Pennsylvania Lubricating Oils. National Petrol. News, vol. 30, 1938, pp. R-504-5, 507-8, 510, 512-3, 515.

Discuss propane dewaxing and deresining process for lubricating oils. Itemized operating costs are given for propane dewaxing, deresining, and combined dewaxing and deresining of Pennsylvania oil.

96. MEKLER, L. A., and BECKER, H. A. Air Preheaters for Petroleum Heaters. Oil Gas Jour., vol. 40, No. 2, May 22, 1941, pp. 88-90, 93, 96, 99; National Petrol. News, vol. 33, 1941, pp. R-162-4, 166,172.

Discuss heat economy resulting from use of air preheaters. Gives cost data for induced-draft plate preheaters of various ratings, examples of operating costs, and heating values of various refinery gases.

97. MILLETT, K. B. Heat Exchangers for Chemical Process Applications. Ind. Eng. Chem., vol. 30, 1938, pp. 367-72.

Gives a table of B.t.u. transferred per dollar of purchase price for heat exchangers for various duties. Most of article is devoted to problems of specifying and design of heat exchangers.

98. MUNSON, C. S., Venture Capital and an Adventurous Industry. Chem. Eng. News, vol. 26, 1948, pp. 1835-7.

A discussion of capital investment in the chemical industry. A chart is presented showing indexes (1939 base) for construction costs, wage rates, commodity prices, and chemical prices for the years 1939 to March 1948.

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99. MURPHREE, E. V., Natural Gas, Coal, Oil Shale as Sources of Liquid Fuels. Oil Gas Jour., vol. 46, No. 49, Apr. 8, 1948, pp. 66, 68-70, 95-6.

Compares estimated costs of gasoline made from petroleum, natural gas, coal and oil shale, and approximate investment and steel requirements. See abstract 47 for table.

100. MURPHY, G. B. Economics of Skimming and Cracking. Oil Gas Jour., vol. 30, No. 11, July 30, 1931, pp. 30, 137-8.

Gives a general relationship between the refining costs when skimming, when cracking to fuel oil, and when running to a nonresidue. Equations are given.

101. NANCE, R. Water Cooling Tower Performance Predicted by Computation. National Petrol. News, vol. 31, 1939, pp. R-316-8.

Discusses some practical considerations relative to selection of a cooling tower and to determination of its principal dimensions. Gives approximate investment costs and operating costs for three sizes of atmospheric cooling towers.

102. NATIONAL PETROL. NEWS. Catalytic Treating Cuts TEL Expense. Vol. 32, 1940, pp. R-454-5.

Digest of a paper by M. W. Conn of Perco Inc. Discusses Perco catalytic desulfurization-process plant construction and operating costs.

103. NATIONAL PETROL. NEWS. Cost 2.3 Cents Per Barrel to Clay-treat Gasoline. Vol. 28, No. 23, June 3, 1936, p. 25.

Gives new equipment cost for Gray clay-treating process at $30 per BPD capacity and treating cost of 2.3 cents per barrel of finished gasoline when treating cracked distillate.

See MANDELBAUM and SWANSON, National Petrol. News, vol. 28, No. 50, Dec. 9, 1936, pp. 69-72.

104. NATIONAL PETROL. NEWS. Says Houdry Units Will Pay Out in 3 Years. Vol. 31, 1939, pp. R-403-4.

Operating costs are given for Houdry catalytic cracking units.

105. NATIONAL PETROL. NEWS. Thermal Poly Process Adapted to Small Gasoline Plant. Vol. 31, 1939, pp. R-194-6, 198, 200, 202.

Digest of a paper read by D. W. Wilson of the M. W. Kellogg Co. Describes three types of thermal polymerization plants. Utility requirements and capital cost are given for a small, simple plant producing 400 BPD of polymer gasoline (10 lb. RVP). Operating costs are given for a

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large plant operating at three capacities: 6,000, 8,000, and 9,500 BSD of saturated butane charge.

106. NELSON, C. C. The Economics of Flue-gas Recirculation and Economizers in Fired Tubular Heaters for Oil Refineries. Oil Gas Jour., vol. 40, No. 2, May 22, 1941, pp. 71-3.

Gives results of tests showing that heat savings by use of either flue-gas recirculation or air preheating did not make up for maintenance and other operating costs.

107. NELSON, W. L. Construction Cost Indexes. Oil Gas Jour., vol. 47, No. 25, Oct. 21, 1948, p. 141.

Indexes are given for cost of refinery construction, over-all construction and equipment, and labor for years 1924-1948.

9 references.

108. NELSON, W. L. Cost of Catalytic Cracking. Oil Gas Jour., vol. 46, No. 18, Sept. 6, 1947, pp. 87, 89.

Summarizes actual refinery construction and operating costs from literature for years 1945-47 for topping, vacuum flash, vacuum distillation, catalytic polymerization, reforming, thermal cracking, fluid cracking, TCC, TCC revamp, propane deasphaltizing, delayed coking, Perco desulfurization, caustic wash, refinery administration and overhead gas plant (TCC), and Perco cycloversion. Royalty charges are given: thermal cracking - 3.0 cents per barrel, catalytic polymerization - 0.5 cent per barrel and TCC and fluid cracking - 5.0 cents per barrel.

11 references.

109. NELSON, W. L. Cost of Steam and Heat in the Refinery. Refiner and Natural Gasoline Manufacturer, vol. 15, 1936, pp. 139-41.

Formula given for computing steam cost based on costs of fuel, labor, depreciation, and chemicals and efficiency of steam generation. Shows distribution of steam consumption in various sections of oil refinery. Gives formula for estimating cost of absorbing heat in pipestill and table showing distribution of direct fuel cost in refinery.

110. NELSON, W. L. Cost of Topping. Oil Gas Jour., vol. 43, No. 38, Jan. 27, 1945, p. 269.

Gives ranges of cost of items (such as fuel, water, steam, labor, depreciation, and overhead) entering into cost of operating topping plant. Copper and doctor sweetening costs also are included.

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111. NELSON, W. L. Dimensions of Pipestills. Oil Gas Jour., vol. 37, No. 52, May 11, 1939, pp. 63, 72.

Formulas are given for calculating cost of various parts of a tubestill (tubes, bends, walls, floors, roof, etc.) for calculating the total cost, and for calculating optimum tube length.

See Oil Gas Jour., vol. 38, No. 3, June 1, 1939, pp. 34, 36.

112. NELSON, W. L. Data for Determining Cost of Pipestills. Oil Gas Jour., vol. 38, No. 3, June 1, 1939, pp. 34, 36.

Gives equation for cost of pipestill based on still design, and equation for economical tube length. Shows graph relating total still cost, effective tube length, and heat-absorption rate. Gives ranges for unit costs.

113. NELSON, W. L. Effect of Capacity on the Cost of a Cracking Plant. Oil Gas Jour., vol. 37, No. 45, Mar. 23, 1939, p. 80.

Shows graph of cracking-plant cost (total, material, labor, and overhead plus profit) vs. capacity. Gives percentage costs for various units of plant for 750, 1,500, and 3,000 BPD capacity and cost balance for cracking-plant operations.

114. NELSON, W. L. Petroleum Refinery Engineering. McGraw-Hill Book Co., New York. 2d ed., 1941, pp. 657-663.

Over-all refining costs and unit-operation refining costs per barrel are given. Ranges of cost are given for various refinery equipment. (Cost data are from years 1927-32, so are of rather questionable value.) Depreciation rates are given (p.655) for various kinds of equipment.

115. NELSON, W. L. Profit Per Barrel of Extra Throughput. Oil Gas Jour., vol. 43, No. 52, May 5, 1945, pp. 113, 115, 116.

Tabulates and discusses range of cost for various items (fuel, water, steam, etc.) entering into operating cost of large and small cracking and topping plants.

116. NOLL, H. D., and BOWLES, V. O. Small-scale Catalytic Cracking. Petrol. Refiner, vol. 24, No. 10, Oct. 1945, pp. 101-8; National Petrol. News, vol. 37, 1945, pp. R-767-71, 841-2, 844; Petrol. Eng., vol. 17, No. 2, Nov. 1945, pp. 107, 110, 114, 116, 118, 120, 122, 124.

Presents process and economic studies on applications of TCC process to the small refinery, giving itemization of equipment and operating costs for various methods of operation. Assumed utility and catalyst costs are given.

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117. NOLL, H. D., HOLDON, K. G., and BERGSTROM, E. V. Simplicity and Flexibility of Thermofor Catalytic Cracking. Petrol. Refiner, vol. 25, No. 5, May 1946, pp. 123-9.

Discusses design of a small-scale integral TCC unit with charge capacity of 1,000 BSD and upward. An economic study gives estimated investment and operating costs and utility requirements for such a unit.

118. OIL GAS JOUR. Catalytic Dehydrogenation. Vol. 46, No. 48, Apr. 1, 1948, p. 128.

A brief discussion, with flow diagram, of the UOP fixed-bed catalytic dehydrogenation process. Approximate direct operating costs are given below for catalytic dehydrogenation of 1,000 BPD of butane, covering the dehydrogenation step only.

Item	Cents/gal. of butylene
Operating labor, supervision, laboratory, etc.	0.95
Maintenance, labor and materials	0.60
Utilities	0.70
Taxes, insurance, administration, general overhead	0.70
Catalyst	0.20
Royalty	0.50
	3.65

119. OIL GAS JOUR. Factors Governing Selection of Lease Storage Tanks. Vol. 41, No. 40, Feb. 11, 1943, p. 73.

Costs are given for bolted steel tanks, including delivery and erection, and for welded-steel tanks.

120. OIL GAS JOUR. Fluid Catalytic Cracking. Vol. 46, No. 48, Apr. 1, 1948, pp. 118-9.

A brief discussion and flow diagram of the fluid catalytic cracking process. The estimated normal utility requirements are given for 60 percent conversion to gasoline and lighter products of a Mid-Continent gas oil in a 2,000-BSD catalytic cracking unit.

121. OIL GAS JOUR. Wooden Tanks for Sour Crude Save Money. Vol. 41, No. 45, Mar. 18, 1943, p. 77.

Costs are given for wooden tanks, delivered and erected, of 250- to 625- barrel capacity.

122. OTTO, F. C. Estimating Cold Insulation Costs. Chem. Eng., vol. 54, No. 5, May 1947, pp. 118-20.

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Prices and installation costs are given for cork insulation for pipe and fittings and corkboard and lagging.

123. OTTO, F. C. Estimating Mineral Wool Insulation. Chem. Eng., vol. 54, No. 7, July 1947, pp. 102-6.

Gives information permitting detailed estimation for mineral-wool insulation as blankets, pipe covering, blocks and boards, cement, and fiber and granules.

124. OTTO, F. C. Estimating Magnesia Insulation Costs. Chem. Eng., vol. 54, No. 9, Sept. 1947, pp. 126-9, 133.

Discusses applications of 85 percent magnesia insulation and its thermal and physical properties. Gives prices and installation costs for pipe covering and blocks.

125. PARKER, F. D. Peacetime Utility of Wartime Petroleum-Refining Processes. Petrol. Refiner, vol. 24, No. 11, Nov. 1945, pp. 117-23; Petrol. Eng., vol. 17, No. 3, Dec. 1945, pp. 116, 119, 122, 124, 127-8.

Discusses production costs for alkylation, butane isomerization, pentane isomerization, catalytic cracking, catalytic reforming, and catalytic polymerization.

18 references.

126. PARKER, H. R. Types of Building Construction for the Chemical Plant. Chem. Met. Eng., vol. 33, 1926, pp. 545-9.

A description of the various building methods and materials ordinarily available, together with appropriate cost data.

127. PERRY, J. H., Editor-in-chief. Chemical Engineers' Handbook. McGraw-Hill Book Co., New York, 2d ed. 1941.

Some data are given on equipment investment and operating cost, as follows: pp. 1636-7, thickeners (unit erection costs, also examples of operating labor requirements, maintenance costs, and total thickening cost per ton of solids); pp. 1692-3, filters (price per square foot for rotary vacuum and percent additional for accessories); pp. 1938-9, total costs and costs per pound of steam capacity for complete boiler plant; pp. 2141-2, stainless steels (comparative prices of various stainless steels as bars, plates, sheets, strip, and billets); pp. 2243-4, materials handling (operating costs for industrial trucks and for dragline scraper conveyors); pp. 2488-90, boiler plants (analysis of costs for parts of boiler plant as dollars per unit area of boiler surface); pp. 2853-6, depreciation rates; pp. 2871-2, cost estimating (a brief discussion).

128. PETROL. ENG. Alkylation and Polymerization. Vol. 18, No. 2, Nov. 1946, pp. 116, 118, 120, 124, 126, 129.

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An analysis of effect on refinery earnings of the two processes: alkylation and polymerization. A graph shows direct operating costs vs. fuel value for 1,000-BPD alkylation and catalytic polymerization units. Other graphs show alkylate and polymer manufacturing costs for 1,000-BPD units related to the equivalent fuel value of the charge stocks.

129. PETROL. PROCESSING. Fischer-Tropsch Process (U.S. Model) Is Means of Supplying Low-cost Oxygen. Vol. 2, 1947, pp. 113-4.

Cost estimate of 95 percent oxygen, produced at rate of 48 MM cubic feet per day at Carthage Hydrocol plant at Brownsville, Tex., is 5 cents per M cubic feet. This includes amortization over 15 years, maintenance at 2 percent of capital investment, and operating labor at $2.per hour. Not included, as they are byproducts of the Hydrocol process, are power (at 14 kw. hr. per M cubic feet of oxygen) and water. Chart shows relative cost of depreciation, labor, power, maintenance, water, and miscellany with respect to plant size. Power is a major cost item, especially for larger plants and with a unit power cost greater than 5 mills per kw. hr.

.See CONWAY, M. J., Petrol. Refiner, vol. 26, No. 6, June 1947, pp. 129-33, for another presentation of these data.

130. PETROL. PROCESSING. Fluid Cracker Charges Heavy Distillate in Postwar Motor Gasoline Operation. Vol. 2, No. 46, 1947, p. 48.

Describes design and operation of fluid catalytic cracking unit of Tidewater Associated Oil Co. at Avon, Calif. Natural catalyst costs have averaged approximately 2 cents per barrel of fresh feed charged.

131. PETROL. PROCESSING. Regeneration Steps Cut Cost of Removing Mercaptans. Vol. 3, 1948, pp. 435-8.

Discusses the development of the process and the factors affecting the catalytic oxidation process for regenerating solutions used in the removal of mercaptans from gasoline. Comparative costs are given for tannin and other catalysts for equivalent solution-regeneration rates.

132. PETROL. PROCESSING. Tannin Solutizer Process Continues to Show Possibilities. Vol. 1, No. 1, Sept. 1946, pp. 7-8.

Operating costs and economic comparison with doctor treatment are given for the tannin solutizer process for mercaptan removal. A reported operating cost for the tannin process is 0.4 to 0.5 cents per barrel, compared with 1.25 to 1.5 cents per barrel for regular solutizer process and about 1 cent per barrel for doctor sweetening.

133. PETROL. PROCESSING. Wastes Reclaimed; Used as Cooling Water. Vol. 1, 1946, pp. 92-3.

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Describes plant for treatment of refinery waste at Talco Asphalt and Refining Division, American Liberty Oil Co.'s plant at Mt. Pleasant, Tex. Reclaimed water is used for cooling. Treatment cost is 15 cents per M gallons.

134. PETROL. REFINER. Continuous Contact Filtration Process (Filtrol Corp.). Vol. 27, No. 9.2, Sept. 1948, pp. 234-5.

A brief description, with flow diagram, of contact filtration of lubricating oils. In a modern contact-filtration unit, where adsorbent handling is accomplished by an automatic mechanical system, the operating cost averages about 8 cents per barrel for a 2,000-BPD plant. Two men per shift can operate this plant.

135. PETROL. REFINER. Crude Oil Desalting Process (Visco Products Co., Inc.). Vol. 27, No. 9.2, Sept. 1948, pp. 220-1.

A brief description, with flow diagram, of the chemical treating of crude-oil emulsions for water and salt removal. Average treating cost ranges from 0.5 to 2.0 mills per barrel of oil desalted. Initial investment is low.

136. PETROL. REFINER. HF Alkylation Process (Phillips Petroleum Co.). Vol. 27, No. 9.2, Sept. 1948, pp. 146-7.

A brief description and flow diagram of the Perco HF Alkylation Process. The following requirements are given for a 3,400-BPD motor alkylate plant:

Utilities

Steam	90,000	lb./hr.
Electricity	950	kw.
Water circulation	4,600	g.p.m.
Water, make-up	247	g.p.m.
Fuel gas	1,200	cu. ft./hr.

Chemicals, lb./month	
Caustic soda	9,850
Bauxite	32,000
HF	27,000
Lime	1,500

Labor (man-hr./day)	
Operation	157
Maintenance	105

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137. PETROL. REFINER. Hydrogen Process (The Girdler Corp.). Vol. 27, No. 9.2, Sept. 1948, pp. 356-7; Oil Gas Jour., vol. 46, No. 48, Apr. 1, 1948, p. 161.

A brief description and flow diagram of the Hygirtol Process for the manufacture of high-purity H_2. The material and utility requirements for production of 1 M cubic foot of H_2 is as follows:

Process material, propane	2.75 gal.
or natural gas	250 cu. ft.
Fuel (gas or oil)	250,000 B.t.u.
Steam	380 lb.
Cooling water (30° F. rise)	1600 gal.
Power	2 kw. hr.
Chemical cost	2 cents
Catalyst replacement	1 to 2 cents
Operating labor	1 man per shift

138. PETROL. REFINER. Propane Decarbonizing Process (The M. W. Kellogg Co.). Vol. 27, No. 9.2, Sept. 1948, pp. 202-3.

A brief description and flow diagram of the continuous propane decarbonizing process. The total operating cost for decarbonizing catalytic-cracking feed stocks varies from 4 to 9 cents per barrel of reduced crude, depending on size of unit and cost of utilities. Volume ratio of propane to oil normally ranges from 3:1 to 5:1, and propane loss amounts to about 0.1 percent.

139. PETROL. REFINER. Unisol Mercaptan Extraction Process (Universal Oil Products Co.). Vol. 27, No. 9.2, Sept. 1948, pp. 256-7.

A brief description and flow diagram of the Unisol Process for mercaptan removal. For most gasolines the combined utility and chemical costs average about 1 to 1.5 cents per barrel.

140. PFARR, J. S. Refiner with 4,500 B/D "Cat-cracker" Cites Advantages in His Operation. Petrol. Processing, Vol. 3, 1948, pp. 666, 668.

A breakdown is given for comparative operating costs of a 1,500-BPD thermal-cracking unit and a 4,500-BPD TCC unit, totaling 74.6 cents per barrel and 38.6 cents per barrel of raw charge, respectively. Throughput and yield data are also compared, and an average utility balance is given for the TCC unit.

141. PFARR, J. S., First Turnaround of Leonard TCC Unit. Petrol. Eng., vol. 19, No. 5, Feb. 1948, pp. 51-4; Petrol. Refiner, vol. 27, No. 3, Mar. 1948, pp. 106-9.

The turnaround of a TCC unit at the Leonard Refineries, Inc., plant is described. Man-hour requirements are broken down by the job item and by the craft for the total plant and for the catalytic section. For description of unit, see Petrol. Processing, vol. 3, 1948, pp. 666, 668.

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142. PIERCE, D. E. A Common Denominator for Repair Costs. Chem. Eng. Progress, vol. 44, 1948, pp. 249-52.

The amount of electrical energy used in a plant is shown to be a good measure of plant activity. The following formula was developed for correlation of plant repair cost with electric power use:

$$C = x(a + by),$$

where: C = total repair cost in dollars per year,
x = kw. hr./yr. ÷ 1,000,
y = cost in dollars per man hour with overhead,
a = repair material index, M kw. hr.,
b = repair labor index, man hours per M kw. hr.

143. PORTER, H. C. Coal as an Auxiliary Source of Gasoline Supply. Petrol. Refiner, vol. 23, No. 8, Aug. 1944, p. 138; Chem. Eng. News, vol. 22, 1944, p. 904.

Discusses cost of gasoline from coal. Gives R. P. Russell's estimated costs per gallon of gasoline (not including depreciation) (1) $2.25 to $2.35 per ton coal: $0.147; (2) $0.05 per M cu. ft. natural gas: $0.06; (3) $1.20 per barrel crude petroleum in modern refinery: $0.051; and (4) $2 per barrel crude: $0.083.

144. POWER, H. H. Petroleum Substitutes: Past and Present Research, Development and Economics. Petrol. Eng., vol. 18, No. 5, Feb. 1947, pp. 70, 72, 75, 78, 80, 82, 84.

Discusses the various synthetic fuel processes, including coal carbonization, shale oil, coal hydrogenation, tar sands, and Fischer-Tropsch synthesis; giving estimated investment and production costs for most of them.

25 references.

145. RANDLE, C. W. Analysis of Southwestern Petroleum Refinery Wages. Petrol. Eng., vol. 15, No. 3, Dec. 1943, pp. 101, 103-4, 106-7, 109, 112, 114.

Gives results of a detailed study of refinery wages in Louisiana, Oklahoma, and Texas. Tables show wages for different occupations and classes.

146. READ, D. A Fluid-catalytic Cracking Unit for the Smaller Refiner. Petrol. Refiner, vol. 25, No. 5, May 1946, pp. 119-22.

Describes design and operation of 2,600-BPD fluid catalytic cracking unit. Estimated utility requirements and operating costs are given for a 2,000-BPD unit.

147. READ, D. Factors in Evaluating Small Refiner's Position. Petrol. Refiner, vol. 26, No. 10, Oct. 1947, pp. 111-2.

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Compares thermal and fluid catalytic cracking installation and operating costs for a 3,500-BSD plant.

148. READ, D. Stopgap Processes Versus Catalytic Cracking. Petrol. Refiner, vol. 26, No. 5, May 1947, pp. 99-110; Oil Gas Jour., vol. 45, No. 52, May 3, 1947, pp. 76-80, 83.

Gives a detailed economic comparison of various processes and operating methods that may be used for improving the octane rating of gasoline. Processes included are selective fractionation, catalytic polymerization, isoforming, thermal reforming, and catalytic cracking. Estimated operating-cost summaries are given for an 1120-BSD thermal reforming unit, 1642-BSD and 2,570-BSD isoforming units, and a 2,870-BSD fluid catalytic cracking unit.

149. REED, R. M. Commercial Production of Pure Hydrogen from Hydrocarbons and Steam. Trans. Am. Inst. Chem. Eng., vol. 41, 1945, pp. 453-62; Petrol. Refiner, vol. 24, No. 9, Sept. 1945, pp. 119-22.

Describes commercial production of pure H_2 from propane and steam by catalytic treatment. Propane, catalyst and utility requirements are given as follows for 1,000 standard cubic feet of hydrogen: 2.75 gallons process propane, 350 M B.t.u. (gross) of fuel (gas or oil), 360 pounds steam, 1,800 gallons cooling water, (30° F. rise), 2 kilowatt hours electric power, and 1 cent chemicals cost.

150. ROUNDS, H. P., and KIERNAN, J. T. Building Fabrication and Comparative Costs. Chem. Met. Eng., vol. 48, No. 5, 1941, pp. 104-6.

Types of framework construction, wall materials, and roofing are discussed, cubic-foot costs being given for buildings of face brick, common brick, hollow tile, corrugated asbestos, and corrugated iron construction.

151. RUBIN, F. L. Shell and Tube Heat Exchangers. Petrol. Refiner, vol. 27, No. 7, July 1948, pp. 139-45.

A discussion of heat-exchanger use, design, and construction. A graph shows relation of cost to surface area for exchanger of internal floating head construction, operating pressure 150 p.s.i., and 16-foot tubes of either steel or Admiralty metal. Relative costs (from E. N. Sieder, Chem. Met. Eng., vol. 46, 1939, pp. 322-5) for exchangers of varying tube lengths are:

Tube length, feet	Cost relative to 16 - ft. tube
8	1.3
12	1.1
16	1.0
20	0.95

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Data are quoted from advertisement by Downington Iron Works (Chem. Eng., vol. 53, Nov. 1946, p. 330) on relative total costs for fixed tube-sheet exchangers with 12-3/4 in. O.D. shell, 10-foot tubes of various metals, carbon steel shell:

Tube side metal	Cost relative to steel
Steel	1.00
Aluminum 3-S	1.29
Copper	1.33
Silicon bronzes (Cu tubes)	1.35
70-30 cupro-nickel	1.51
Stainless steel 304	2.00
Monel	2.09
Stainless steel 347	2.17
Nickel	2.26
Stainless steel 316	2.34
Inconel	2.34

For larger exchangers the relative cost of alloy steel will probably be considerably more than above values.

152. RUSSELL, R. P. Costs and Requirements in Materials for Making Gasoline from Coal. National Petrol. News, vol. 35, 1943, pp. R-421-2, 424-6; Am. Gas Assoc. Monthly, vol. 26, No. 2, Feb. 1944, pp. 87-92.

Presents graphically the investment costs, materials required for construction and operation, and operating costs for the production of motor gasoline from coal, natural gas, and petroleum. States belief that order of use of natural resources should be petroleum, natural gas, oil shales and tar sands, and finally coal, for production of gasoline and other petroleum products.

153. SAEGEBARTH, A., BROGGINI, A. J., and STEFFEN, E. High Octane Number Blending Stocks Produced by Solvent Extraction. National Petrol. News, vol. 29, No. 22, June 2, 1937, pp. 51-2, 54-5, 57-8.

Describe liquid SO_2 extraction process and semicommercial plant. Utility requirements and operating costs are given. Total operating costs for a 3,000-BPD unit, including maintenance, repairs, and royalty, are 11.4 cents per barrel of charge for operation at 0 °F. and 12.5 cents per barrel for minus 60 °F.

154. SCHAFFNER, R. M., and KOEHLER, W. A. Determination of the Performance and Operating Costs of a Commerical Dryer. Trans. Am. Inst. Chem. Eng., vol. 35, 1939, pp. 303-22.

Presents a study of the operating characteristics and drying costs for a commerical temperature-and humidity-controlled tray drier.

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155. SCHAPHORST, W. F. Calculating Construction Costs. Ind. Eng. Chem., News Ed., vol. 19, 1941, p. 1151.

A monograph is given for estimating cost of a building of standard design from the dimensions.

156. SCHRADER, R. J. Estimating Chemical Piping Costs. Chem. Eng., vol. 54, No. 1, Jan. 1947, pp. 109-10.

Gives formula and factors for estimating pipe-installation labor for stainless-steel, wrought-steel, glass, porcelain, and saran pipe. Gives table of prices for pipe and tubing of various metals, glass, saran, tygon, neoprene, and porcelain, and of different kinds of valves and fittings.

157. SCHROEDER, W. C. Comparison of Major Processes for Synthetic Liquid Fuels Chem. Industries, vol. 62, No. 4, April 1948, pp. 574-7, 682.

Discusses production of synthetic fuels by retorting oil shale, gas synthesis from coal or natural gas, and coal hydrogenation.

158. SCHULZE, W. A., and GREGORY, L. S. Solution and Gasoline Losses Low in Copper-Sweetening Process. National Petrol. News, vol. 28, No. 41, Oct. 7, 1936, pp. 34, 38-40, 75.

Discusses chemistry of the copper chloride (Perco) sweetening process Operating and chemical costs for a commercial installation are compared with the costs of conventional doctor treating.

159. SHANLEY, W. B., and EGLOFF, G. Midget Polymerization and Midget Iso-octane Units. National Petrol. News, vol. 31, 1939, pp. R-234, 236-40.

Describes operation of UOP "midget units" for polymerization of olefins followed by hydrogenation of polymers to iso-octane. Installed cost of unit processing 125 M to 1,500 M cu. ft. per day of cracked gas (18 to 215 BPD of gasoline) is approximately $15,000 to $35,000. Utilities for a unit processing 500 M cu. ft. per day of gas are: fuel - 650 M B.t.u./hr., water - 4,000 g.p.h., process steam - 550 lb./hr., and compressor power - 35 hp.

160. SIEDER, E. N. Cost Relations of Heat Exchangers. Chem. Met. Eng., vol. 46, 1939, pp. 322-5.

A thorough discussion, with graphs, of the effect of design factors such as tube diameter and length, working pressure and heat exchange surface on cost of heat exchangers. Relative costs only are given, not dollar costs.

161. SIEDER, O. E. Considerations in Industrial Plant Site Cost. Chem. Eng., vol. 54, No. 5, May 1947, p. 117.

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Some cost data are given on plant site, roads and parking areas, railroad sidings, fences, and wells.

162. SIMPSON, T. P., NICHOLLS, E. S., and PAYNE, J. W. Recent Advancements and Applications of the Thermofor Kiln in the Petroleum Industry. Trans. Am. Inst. Chem. Eng., vol. 36, 1940, pp. 841-55; National Petrol. News, vol. 32, 1940, p. R-442. (A digest of the article.)

Operating data are given for the Thermofor kiln. Relative operating costs are given for Thermofor and for multiple-hearth regeneration of clay used in percolation filtration.

163. SITTENFIELD, M. Petroleum Chemical Detergents. Chem. Eng., vol. 55, No. 6, June 1948, pp. 120-2.

The process is described for the production of alkyl aryl sulfonate detergents from petroleum. A plant producing 15 TPD of 60 percent active material costs about $75,000 to $85,000, the major cost item being the drying equipment. A breakdown of the manufacturing cost is given, the total being estimated as 14 cents per pound of 60 percent active material and 10 cents per pound of 40 percent active material.

164. SMOLEY, E. R. Combination Cracking Economics. National Petrol. News, vol. 30, 1938, pp. R-203-4, 206-7, 210.

Gives curves showing investment costs and direct operating costs of 2,000 to 20,000-BPD units for atmospheric topping and multiple-coil topping and cracking. Also shows return on investment in cracking unit under varying operating conditions and costs, on crudes costing $1.20 to $1.60 per barrel at refinery. Gives average breakdown of direct operating costs.

165. SMOLEY, E. R., and BOWLES, V. O. Polyform and Gas Reversion Processes for Higher Octane Gasoline. National Petrol. News, vol. 33, 1941, pp. R-364, 366, 368.

Discusses operation of naphtha polyform and gas reversion units, especially with respect to conversion of propane and butanes to high-octane gasoline. Some operating cost data are given for butane and propane conversion in these units.

166. STEVENS, R. W. Equipment Cost Indexes for Process Industries. Chem. Eng., vol. 54, No. 11, Nov. 1947, pp. 124-6.

Gives graph comparing building cost and equipment cost indexes for 1910 to 1947. Also gives tabulation of Marshall and Stevens equipment cost indexes for eight process industries and four related industries for years 1913 to June 1947.

167. STITT, H. E. Build the Plant to Fit the Process. Chem. Met. Eng., vol. 38, 1931, pp. 196-9.

Presents, with illustrations, relative cost of various types of factory floor construction, wall construction, and roofs and roof

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waterproofings. Shows cost comparison and cost breakdown for single and multi-story buildings.

168. STUEVE, W. H. Analysis of Power Requirements in Refinery Operations. Petrol. Eng., vol. 10, No. 9, June 1939, pp. 120, 122, 124-6, 128.

Gives tables of electrical and mechanical energy, water and steam requirements for "skimming", "cracking", and "complete" oil refineries based on a study of 44 refineries.

169. THAYER, C. H., LASSIAT, R. C., and LEDERER, E. R. Houdry Two-stage Dehydrogenation Catalytic Process for Manufacture of Butadiene. National Petrol. News, vol. 34, 1942, pp. R-305-6.

Gives estimated cost of Houdry combined 2-stage dehydrogenation and single-stage purification plant for production of 15,000 tons per year of butadiene. Breakdown is given of material requirements for plant construction and of estimated plant operation costs.

170. THEISINGER, W. G. Fabrication Costs of Boilers, Tanks, and Pressure Vessels as Affected by Plate Widths. Petrol. Refiner, vol. 24, No. 2, Feb. 1945, pp. 121-7.

Detailed discussion of fabrication costs of welded vessels formed from steel plate. Possible savings are shown for use of extra-width plates in place of additional welding when narrower plates are used. Brief discussion of costs for fabrication of low-alloy, clad and solid stainless steels, and nonferrous metals.

171. TUTTLE, R. B. Steam Power Plants. Oil Gas Jour., vol. 46, No. 1, May 10, 1947, pp. 72-4, 95.

Steam costs are given for several steam plants. Two similar plants showing 75 percent over-all efficiency, and well-maintained, produced steam at an average cost of $0.1805 per M lb, (not including depreciation). Breakdown is given of average operating cost. Another plant with an inexpensive installation and producing about 100 M lb. per hr. of 250 p.s.i. superheated steam at 500 °F. showed production cost of $0.1635 per M lb. (including depreciation). Two other plants producing on a yearly average 40 M pounds per hr. with an efficiency of 55 to 65 percent gave steam costs of $0.2248 per M pound (not including depreciation).

172. TYLER, C. Chemical Engineering Economics. McGraw-Hill Book Co., New York, 3d ed., 1948.

A chapter on process equipment costs gives data by H. Bliss on cost of the following items: pipe and tubing, pipe fittings, valves, heat exchangers, filters, thickeners, pressure vessels and pressure fractionating columns, evaporators and crystallizers, absorption towers and packings, tanks, storage vessels and linings, liquid and gas pumps, crushing and grinding equipment, driers, reaction vessels, and electric motors. (See abstracts 10 and 11.)

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Also included is a short discussion of cost estimating by R. Williams. Installed costs are given for heat exchangers and tanks. Other chapters include a general discussion of cost estimating, the ENR construction cost index, electric power cost as related to demand, and a table giving the estimated average life of chemical equipment.

173. VAN VOORHIS, M. G. One-hundred Refineries Now Converting Mercaptans with Copper Salts. National Petrol. News, vol. 32, 1940, pp. R-122-3, 126, 129.

Describes three plants using Cu salts in Perco's solid and liquid processes for converting mercaptans to disulfides. Examples are given of chemical and operating labor costs.

174. VAN VOORHIS, M. G., The Houdry Process. National Petrol. News, vol. 31, 1939, R-346-7, 349, 350, 352, 354-5, 358, 360-2, 364, 366, 368.

Detailed description (with flow charts) of Magnolia's 15,000-BPD Houdry catalytic cracking unit. Cost of unit was $2,980,000. Houdry and thermal cracking units are compared on basis of utility and equipment requirements.

175. VILBRANDT, F. C., Chemical Engineering Plant Design, 2nd ed., 1942, McGraw-Hill Book Co., New York.

Chapter XII, pp. 306-365, gives a good discussion of preconstruction cost estimating. Considerable data are given for equipment investment and operating costs, depreciation rates, maintenance, buildings, etc. Extensive bibliography.

176. WADE, H. N., Value of Polymerization in Natural Gasoline Plant Operations. National Petrol. News, vol. 29, 1937, pp. R-347-8, 350-2.

Describes Unitary Thermal Polymerization Process and Dubbs Catalytic Process for polymerization of cracked butanes and propane. Plant investment cost estimates are given. Operating costs are given for the Unitary Thermal Process.

177. WEBER, G., Sulfur from Sour Gas. Oil Gas Jour., vol. 45, No. 44, Mar. 8, 1947, pp. 58-9, 84, 87.

Describes process for sweetening sour gas and recovering byproduct sulfur. Rich solution from Girbotol gas purification unit goes to S plant, where H_2S is converted to free S by a modified Klaus process. Estimated investment cost for S plant is $5,000 per TPD of S production. Prevailing price of S is $16 per ton.

178. WEIL, B. H. Shale Oil, Other Substitutes, and the Petroleum Shortage. National Petrol. News, vol. 35, 1943, R-348-9.

Gives estimated costs of gasoline: Fischer-Tropsch, from coal - 18 cents per gallon, from natural gas - 9 to 12 cents per gallon;

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coal hydrogenation - 16 cents per gallon (with a far-distant potentiality of 12 cents per gallon) these costs not including profit and compared with petroleum gasoline at 5 cents per gallon. Estimated cost of shale-oil production of not more than $2 per barrel, gasoline cost of 5 to 12 cents per gallon. Estimated investment cost to mine and retort shale and thermally crack to gasoline would be $1,500 to $3,000 per BPD of gasoline as compared to $2,500 (in 1937) for producing, transporting and refining petroleum.

179. WEIL, B. H., and WEINRICH, W. Oil Shale and Shale Oil. A Survey. Part 1. Oil Gas Jour., vol. 41, No. 50, Apr. 22, 1943, pp. 48, 51, 53, 55, 72. Part 2. Oil Gas Jour., vol. 41, No. 51, Apr. 29, 1943, pp. 73, 75, 76, 79.

A general discussion of the oil-shale industry, including reserve estimates, retorting methods, products, hydrogenation of oil shale and shale oil, mining costs, retorting costs, and capital investment required

27 references.

180. WHITMAN, W. G., and FUWA, T. Cost of Filtration Equipment and Operation. Chem. Met. Eng., vol. 30, 1924, pp. 355-9.

Gives approximate figures on investment costs and operating cost of filters (press, pressure leaf, and continuous vacuum). Outlines method of estimating filtration costs, emphasizing major items of expense characteristic of the various filters.

181. WILCOXON, B. H. Unit Cost of Some Complete Plants. Chem. Eng., vol. 54, No. 5, May 1947, p. 112.

Gives table of approximate unit costs of chemical plant construction for various products for years 1942-4.

182. WILLIAMS, JR., R. Six-tenths Factor Aids in Approximating Costs. Chem. Eng., vol. 54, No. 12, Dec. 1947, pp. 124-5.

Shows verification of "six-tenths factor" used in estimating cost of equipment of size differing from a unit of known cost. Formula given is: $y_2 = y_1 (x_2/x_1)^{0.6}$, where x_1 and x_2 are capacities and y_1 and y_2 are costs of the first and second unit of equipment, respectively.

183. WILLIAMS, JR., R. Standardizing Cost Data on Process Equipment. Chem. Eng., vol. 54, No. 6, June 1947, pp. 102-3.

Gives cost data for steel tanks and for heat exchangers, including condensers and calandrias. Points out need of data that will permit selection of a definite unit cost rather than a range in cost.

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184. WILSON, R. E., and ROBERTS, J. K., Petroleum and Natural Gas - Uses and Possible Replacements. Petrol. Processing, vol. 2, 1947, p. 332.

Brief abstract of paper. Gives table comparing investment costs per BPD in petroleum industry for various operations for 1939 and 1947, respectively: skimming - $180, $300; topping and thermal cracking - $600, $1,000; topping and catalytic cracking - $900, $1,500; synthesis oil from natural gas - $2,100, $3,500; and synthesis oil from coal - $3,000, $5,500.

185. WORLD PETROL. Oil from Shale. Vol. 19, Aug. 1948, pp. 49-50; UOP Libr. Bull. of Abs., vol. 23, Sept. 1, 1948, p. 140.

Discusses Bureau of Mines mining and retorting operations. Mentions hydrogenation of crude oil as preliminary to refining. Gives estimated cost of shale oil as $2 to $2.50 per barrel, including $0.70 for mining and $1.30 to $1.80 for crushing and retorting. Compares estimated cost of liquid fuels from coal, shale, natural gas, and petroleum as of Feb. 1948.

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